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Investigation of Performance Properties of Knitted Fabrics Produced from Splittable Microfilament Yarns

Ayırma Tipi Mikrofilament İpliklerden Üretilmiş Örme Kumaşların Performans Özelliklerinin İncelenmesi

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INVESTIGATION OF PERFORMANCE PROPERTIES OF KNITTED FABRICS PRODUCED FROM SPLITTABLE MICROFILAMENT YARNS

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ABSTRACT: Splittable microfiber is an important type of microfibers. In the scope of this study, the performance properties of single jersey knitted fabrics produced from splittable microfilament yarns are investigated before and after the splitting process. For this aim three knitted fabric samples are produced as single jersey structure with three different fabric densities (loose, medium, tight) and one half of the each sample are treated to splitting process. In doing so, six fabric samples are obtained. Air permeability, water vapour permeability and bursting strength performances of the samples are tested. By this way, it is intended to make a comparative study on the performance properties of knitted fabrics produced from conventional filaments (before splitting process) and microfilaments (after splitting process) for different fabric densities. In order to understand the statistical importance of filament type and fabric density on knitted fabric performance properties, two way ANOVA (Analysis of variance) is performed.

Keywords: Splittable microfilament, microfiber, knitted fabric, permeability, bursting strength

AYIRMA TİPİ MİKROFİLAMENT İPLİKLERDEN ÜRETİLMİŞ ÖRME KUMAŞLARIN PERFORMANS ÖZELLİKLERİNİN İNCELENMESİ

ÖZET: Ayırma tipi mikrofilamentler önemli bir mikrolif çeşididir. Bu çalışma kapsamında, ayırma tipi mikrofilamentlerden üretilmiş süprem örgü kumaşların ayırma işlemi öncesinde ve sonrasındaki performans özellikleri araştırılmıştır. Bu amaçla, üç farklı kumaş sıklığında (gevşek, orta, sıkı), süprem yapısında üç örgü kumaş numunesi üretilmiş ve her birisinin yarısı ayırma işlemine tabi tutulmuştur. Böylelikle, altı kumaş numunesi elde edilmiştir. Numunelerin hava geçirgenliği, su buharı geçirgenliği ve patlama mukavemeti performansları test edilmiştir. Bu şekilde, farklı kumaş sıklıklaı için, konvansiyonel filamentlerden (ayırma işlemi öncesi) üretilmiş örgü kumaşlarla mikrofilamentlerden (ayırma işlemi sonrası) üretilmiş örgü kumaşların performans özellikleri üzerine karşılaştırmalı bir çalışmanın yapılması amaçlanmıştır. Filament çeşidinin ve kumaş sıklığının örgü kumaş performansına etkisini istatistiksel olarak incelemek amacıyla iki yönlü ANOVA yapılmıştır.

***Anahtar Kelimeler*:** Ayırma tipi mikrofilament, mikrolif, örgü kumaş, geçirgenlik, patlama mukavemeti

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1. INTRODUCTION

Synthetic fiber industry has been enforced to make developments due to the increasing performance demand from textile products. One of the most important developments in synthetic fiber industry, is absolutely producing extremely fine fibers which are named as microfibers [1]. Until today, there is no exact definition for microfibers. But common opinion is defining a fiber finer than 1 dtex or 1 denier as microfiber. 1 dtex polyester fiber has a fiber diameter of approximately 10 µm [2]. Microfibers provide light weight, softness, good drapability, high water absorbency, quick dry and many distinguishing properties for different end uses such as apparel, sportswear and home furnishing [1]. Microfibers are classified into two types, continuous filament type and staple type. Continuous filament type microfilaments can be produced by different methods namely; alkaline weight reduction, direct spinning and bicomponent spinning. Splitting method is a type of bicomponent spinning. In split spinning, the starting fibre consists of segments of two different polymers. Each wedge of polymer *A* has a wedge of polymer *B* on either side. The general production principle of splittable fibres is given in Figure 1. The fibres are designed to split into the wedges by different treatments to produce the ultimate microfiber. Segmented pie fibers are, therefore, known as '***splittable microfibres***' [3].

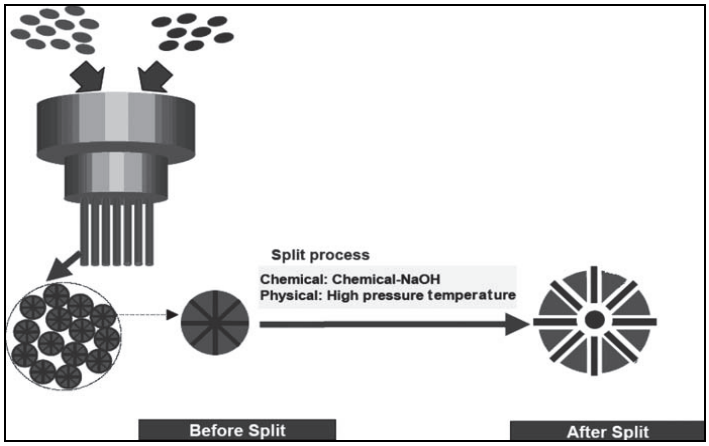

Figure 1. Schematic diagram of the splittable microfiber production [3]

Splittable N/P(Nylon/Polyester) microfibres are widely used for artificial suede, wiping cloths, peach-skin fabrics, silk-like fabrics, and air-permeable and water-proof fabrics due to their many advantages of enhanced softness, bulkiness, smoothness, high aesthetics and good comfort properties compared with regular polyester fibres. Moreover, splitting N/P microfibres yields fabrics with fine, closely packed and aligned capillary columns of water between the fibres and larger surface areas on the fabrics, resulting in excellent absorbency. The triangular cross-sectional shape and ultra fineness of these N/P microfibres, formed by splitting composite fibres, provide the microfibre fabric with excellent wipeability due to the sharp-edged effect of split microfibers [3].

In the literature there are some studies which deal with the performance properties of fabrics knitted from microfilament yarns. But in these studies, microfilament yarns produced by direct spinning method are used [4-7, 1, 8]. On the other hand, many workers investigated the performance properties of splittable microfilament knitted fabrics. Park et al. [9] studied the effects of splitting and finishing on absorption/adsorption properties of split polyester microfiber knitted fabrics. A split N/P (nylon/polyester, 25:75 weight %) conjugate fiber (120d/72f multi filaments) pile knit was used as the material for the splitting process. Ranges of microfiber fabrics produced under various splitting conditions were used for evaluating absorption properties. Hyung Lee et al. [10] studied the absorption properties of split-type microfiber knitted fabrics by measuring the change in the color depth. Kim et al. [11] studied the effect of chemical splitting on the water absorption and mechanical properties of a split-type nylon/polyester (N/P) microfiber pile knit under various alkaline hydrolysis treatment conditions.

In this study, it is aimed to investigate the performance properties of single jersey knitted fabrics produced from splittable microfilament yarns before and after splitting process. By this way, it is intended to make a comparative study on the performance properties of knitted fabrics produced from conventional filaments (before alkali treatment) and microfilaments (after alkali treatment). Also, it is intended to investigate the effects of fabric density on the performance properties of single jersey knitted fabrics before and after splitting process regarding the fabric structure. Since the spitting process affect the fabric solid structure in terms of porosity between the yarns and fibers, the air permeability and water vapor permeability performances of the fabric samples were compared before and after splitting process. The spitting process is achieved by degrading the polyester component via alkali treatment. In order to see whether the alkali treatment cause deterioration in fabric strength or not, the bursting strength performances of the fabric samples were also compared.

2. MATERIAL AND METHODS

In this study, it is aimed to investigate the structural and performance properties of knitted fabrics produced from splittable microfilament yarns before and after splitting process. By this way, it is intended to make a comparative study on the performance properties of knitted fabrics of conventional filaments (before alkali treatment) and knitted fabrics of microfilaments (after alkali treatment). In this context, Teijin brand 50-50% polyester-nylon 84 dTex/20f splittable yarn (segmented pie/16 segments) is used. Cross sectional SEM (Scanning Electron Microscopy) view of this yarn is seen in Figure 2.

For the quality and tenacity parameters of the sample yarn, 4 measurements were done with with Uster Tester 4S and Uster Tensorapid 3 test devices and the results are given in Table 1.

Three knitted fabric samples are produced with different levels of fabric density as loose, medium and tight. Knitted fabric

samples are produced as single jersey structure, by a 3.5” gauge, 22 fein and one feeder sample circular knitting machine at 20±2 rev/min production speed. A piece of these three samples are then chemically treated for splitting.

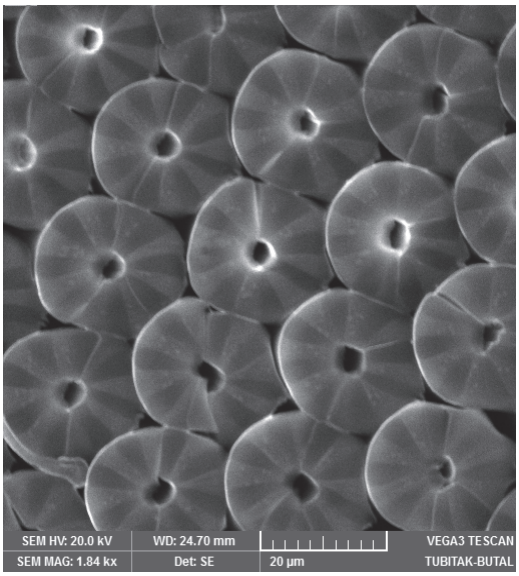

Figure 2. Cross sectional SEM view of splittable microfilaments (1840 X)

At present, there are many ways to split bicomponent fibers into microfibers. These ways can be divided into three categories: chemical procedures, thermal procedures and mechanical procedures. Chemical procedures are to use some chemicals to process the bicomponent fibers so that different components in fibers can separate to each other. In this way, chemicals can be evenly applied to fiber materials. Chemical procedures mainly include alkali deweighting, acid process and chemicals swelling. Alkali deweighting is the most commonly used splitting method in the industrial production of microfibers at present. In this procedure, alkaline solution reacts with one of the two polymers in fiber and made it degraded. When the polymer is degraded to some extent, the two polymers in bicomponent fiber can automatically separate to each other. But this method will cause greater damage to fibers. Although with the alkali concentration, reaction time and temperature increases, splitting rate of fibers increases, the polymer is deweighted more, resulting in lower fiber strength and output [12].

Table 1. Quality and tenacity parameters of the sample yarn

Property	Value
U%	9.37
CVm	11.45
Thin place (- 50%/km)	66.3
Thick place (+50%/km)	0
Neps (+200%/km)	3365
Hairiness	3.09
Tenacity, gf	281.5
Breaking elongation, %	51.6

In this study, alkali deweighting method is used. The conditions of the alkali deweighting method are proposed by Teijin (producer of the splittable yarn) as a receipt. For this aim, a sample dyeing machine is used. Sample fabrics are treated with NaOH, at 30 g/l concentration and 1:30 liquor ratio. Treatment temperature is 90°C and duration is 30 minutes. After alkali treatment, samples are washed with tap water and neutralized with PH 4-5 acetic acid solution. Treated fabric samples are then dried in room conditions.

Surface views of the sample fabrics before and after the alkali treatment under 60X magnification are seen in Figure 3.

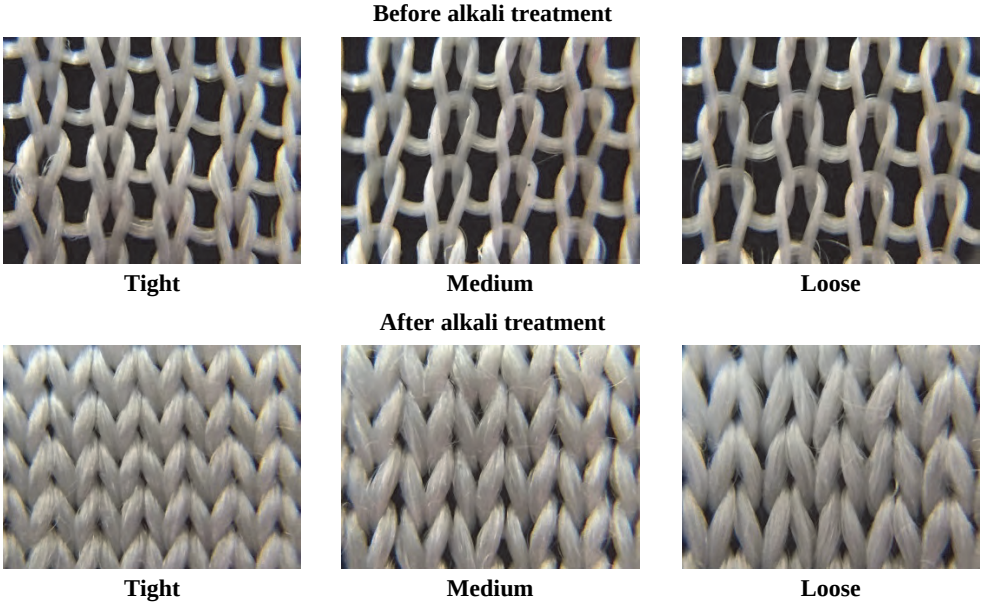

Figure 3. Surface views of fabrics before and after alkali treatment

All fabric samples were conditioned according to TS EN ISO 139 [13] before the tests and the tests were performed in the standard atmosphere of 20±2ºC and 65±4% relative humidity. Fabric mass, thickness, loop density and loop length properties of samples were determined according to TS EN 12127:1999 [14], TS 7128 EN ISO 5048:1998 [15], TS EN 14971:2006 [16] and TS EN 14970:2006 [17], respectively. The results are given in Table 2.

Air permeability, bursting strength and water vapour permeability properties of the samples were determined according to TS 391 EN ISO 9237:1999 [18], TS EN ISO 13938-2:2003 [19] and BS 7209:1990 [20], respectively. Air permeability test was done with digital air permeability test device at 100 Pa pressure drop and 20 cm² test area. The air permeability tests were performed over ten measurements for each fabric sample. Bursting strength test is done with digital pneumatic bursting strength test device and five specimens were used for each fabric sample.

Water vapour permeability test was done according to evaporative dish method [20]. Three test specimens and reference fabric were mounted over the test dishes containing distilled water at 20±2ºC. These test dishes were placed on a rotating turntable. The samples and standard reference fabric were rotated with turntable for one hour to establish equilibrium of water vapour pressure gradient across the sample. After the equilibrium was established, the mass of the dishes were determined via digital balance with 0.001 g sensitivity. The turntable with dishes was then rotated within controlled atmosphere for a further period of at least 5 hour or an overnight of 16 hour. The mass of the dishes were weighed after the selected period. The difference between these successive weighing of the dish is the amount of water permeated (*M*) through the specimen.

The water vapour permeability (*WVP*) in $g/m^2/day$ is given by the equation:

$$WVP = \frac{24M}{At} \quad (1)$$

Where,

M = loss in mass of the dish over the time period in grams

t = time between successive weightings of the assembly in hours

A = area of the exposed sample, 5.41×10^{-3} m^2

Also, the water vapour permeability index (*I*) is given by means of the following equation (2):

$$I = \frac{(WVP)_f}{(WVP)_r} \quad (2)$$

Where,

$(WVP)_f$: is the mean water vapour permeability of the fabric under test

$(WVP)_r$: is the water vapour permeability of the reference fabric

In order to understand the statistical importance of filament type and fabric density on knitted fabric performance properties, two way ANOVA was performed. For this aim the statistical software package SPSS 21.0 was used to interpret the experimental data. All test results were assessed in 95% confidence interval.

3. RESULTS AND DISCUSSION

All test results; Air permeability, bursting strength and water vapour permeability of the samples are given in Table 3. The results are discussed in detail separately at following.

Table 2. Structural properties fabric samples

	Before treatment			
Sample	**Thickness, mm**	**Fabric mass, g/m²**	**Loop density, loops/cm²**	**Loop length, mm**
Loose	0.26	67	81	4.5
Medium	0.27	72	121	4.2
Tight	0.31	90	144	3.7
	After treatment			
Sample	**Thickness, mm**	**Fabric mass, g/m²**	**Loop density, loops/cm²**	**Loop length, mm**
Loose	0.38	85	120	4.2
Medium	0.38	95	143	3.8
Tight	0.38	105	196	3.5

Table 3. Test results

Sample	Before treatment		
	Air Permeability, mm/sn	**Bursting Strength, kPa**	**Water Vapour Permeability, g/m²/day**
Loose	6310	214.9	901.68
Medium	5696	247.3	981.62
Tight	5355	266.6	943.82
Sample	**After treatment**		
	Air permeability, mm/sn	**Bursting Strength, kPa**	**Water Vapour Permeability, g/m²/day**
Loose	1411	233.5	887.9
Medium	864	243.8	769.8
Tight	686	259.3	754.6

3.1. Air Permeability

Figure 4 exhibits the air permeability of knitted fabric samples before and after alkali treatment.

It is clear from Figure 4 that, there is a considerable air permeability difference between the alkali treated and untreated samples. The air permeability values are pretty low after alkali treatment. Since, conventional filaments in yarn structure are splitted by alkali treatment and microfilaments are obtained. In this situation, two phenomenons should be considered that, loop density and fabric thickness values of the samples are increased (Table 2) after splitting process. Since loop density change is much more than the thickness change, it can be said that the loop density increase after splitting has greater effect on the air permeability of the samples than that of thickness increase.

The air passage through the fabric occurs through the pores between yarn loop intersects and open spaces between the fibres of yarn structure. It is obvious that, the pores between the yarns diminished after splitting process for all samples (Figure 3). As the pores between the yarns get smaller, the air passage between these yarns through the fabric becomes harder. Also, as the number of filaments in yarn cross section increases after splitting process, the total specific surface area of the filaments in yarn cross section increases and the dimensions of the pores between the filaments decrease. This situation causes a higher drag resistance to air flow through the fabric. Consequently, air permeability decreases owing to losing more kinetic energy during air passage.

On the other hand, higher fabric thickness causes a longer path for air that passes through the fabric. The kinetic energy of the air decreases and lower air permeability occurs due to higher fabric thickness.

It is seen that air permeability values of samples are decreased as the fabric structure gets more compact for both alkali treated and untreated samples. It can be seen from Table 2 that, as the fabric structure become looser, the loop density of the samples decrease. Increased loop density of the samples cause higher amount of textile material in unit area and air encounter more number of drags in unit area during passing through the fabric. So that the loose structures permit air passage through the fabric more easily than compact ones and air permeability is higher for loose structures.

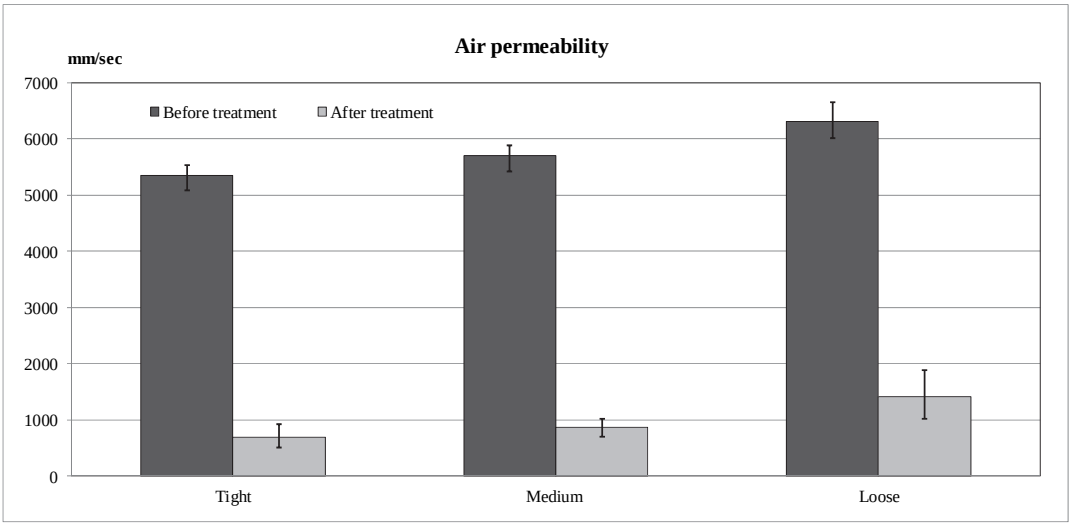

Figure 4. Air permeability of samples

Table 4 represents the ANOVA results for air permeability of the samples.

Table 4. Two way ANOVA for air permeability

Source		Sum of squares	Degree of freedom	Mean square	F	Significance
Intercept	Hypothesis	663770228.956	1	663770228.956	191.684	0.005
	Error	6925830.946	2.000	3462842.525		
treatment	Hypothesis	333224229.384	1	333224229.384	4944.979	0.000
	Error	134918.760	2.002	67386.374		
Fabric density	Hypothesis	6934457.073	2	3467228.536	51.415	0.019
	Error	134871.831	2	67435.916		
treatment * fabric density	Hypothesis	134871.831	2	67435.916	2.358	0.105
	Error	1486958.889	52	28595.363		

According to ANOVA results, splitting treatment, in other words filament type, has a statistically significant effect on air permeability ($p=0.000<0.05$). Also, fabric density has a statistically significant effect on air permeability ($p=0.019<0.05$) in 95% confidence interval. In addition, according to pairwise comparison tests, among tight, medium and loose density levels fabrics produced with these densities have statistically different air permeability results, in 95% confidence interval. In other words, none of the density levels have a statistically similar effect on air permeability to another.

3.2. Bursting Strength

Bursting strength of alkali treated and untreated samples are given in Figure 5. As seen from Figure 5, bursting strength values of samples decrease as the fabric structure gets looser for both alkali treated and untreated samples. This is a probable result of lower number of loops per unit area for looser structures. The samples with lower number of loops in unit area cannot withstand the forces applied for bursting as much as that of high density samples. So, lower bursting strength values are observed for looser fabrics for both alkali treated and untreated samples. On the other hand, it can be stated that, there is very little decrease of bursting strength after alkali treatment for tight and medium fabric structures whereas, a very little increase is detected for loose sample. It can be attributed to the fact some amount of polyester fiber within the splittable filament is degraded by means of alkali treatment and so the yarn strength decreases. The decrease in yarn strength leads to decrease in fabric bursting strength. As given in Table 2, the loop density in unit area increases after the alkali treatment. This loop density increase compensates the decrease in fabric strength for all samples. So, the decrease in fabric bursting strength is restricted with a little amount. When the fabric loop densities after alkali treatment are compared (Table 2), it can be seen that the increase in loose fabric (48.15%) is much more than that of tight and medium fabric samples (36.11% and 18.18% respectively). Thus, the bursting strength increase for loose fabric after alkali treatment can arise from higher amount of increase in loop density per unit area.

So, it can be concluded that there is no consistent trend for samples considering bursting strength for different fabric densities. In other words, alkali treatment does not cause deterioration on bursting strength.

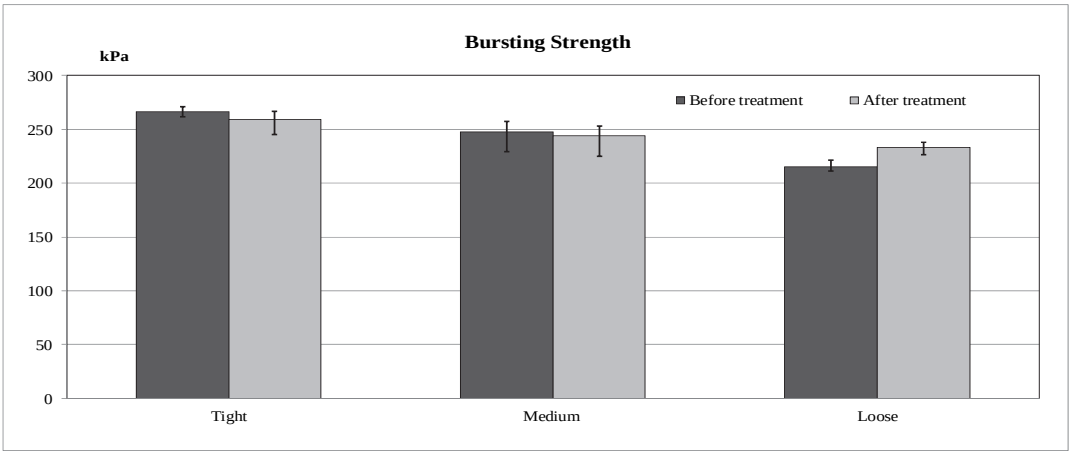

Figure 5. Bursting strength of samples

Table 5 represents the ANOVA results for bursting strength of the samples.

Table 5. Two way ANOVA for bursting strength

Source		Sum of squares	Degree of freedom	Mean square	F	Significance
Intercept	Hypothesis	1789693.025	1	1789693.025	475.852	0.002
	Error	7522.065	2	3761.032		
treatment	Hypothesis	52.801	1	52.801	0.108	0.773
	Error	973.865	2	486.932		
Fabric density	Hypothesis	7522.065	2	3761.032	7.724	0.115
	Error	973.865	2	486.932		
treatment * fabric density	Hypothesis	973.865	2	486.932	7.696	0.003
	Error	1518.484	24	63.270		

According to ANOVA results, filament type (splitting treatment) and fabric density have statistically insignificant effects on bursting strength with significance values of $p=0.773>0.05$ and $p=0.115>0.05$ (in 95% confidence interval), respectively.

3.3. Water Vapour Permeability

Figure 6 shows the water vapour permeability of samples before and after the alkali treatment.

Water vapour permeability of the samples exhibits a decrease after alkali treatment. This is a probable result of increased density and thickness values due to alkali treatment as seen from Table 2 and decreased porosity as seen from Figure 3. Decreased porosity and increased density cause a more compact structure for the fabric and increased thickness cause a longer path for water vapour passage. Consequently, water vapour permeability of the samples decrease owing to these mentioned factors. Since, water vapour can diffuse through a textile structure through the air spaces between the fibers and the yarns and along the fiber itself [21] and diffusion is more likely to occur in fabrics that have larger interstices or open spaces within the structure. In other words, looser structures will enhance the movement of moisture vapor [22, 23]. On the other hand, it is seen that the water vapour permeability difference between the alkali treated and untreated samples are minor for tight and medium density samples whereas, the difference is negligible for loose samples.

Regarding the effect of fabric density on water vapour permeability, it is seen that WVP of the untreated samples do not have a consistent trend. There is slight increase in WVP as the fabric structure gets looser for alkali treated samples.

Table 6 represents the ANOVA results for water vapour permeability of the samples.

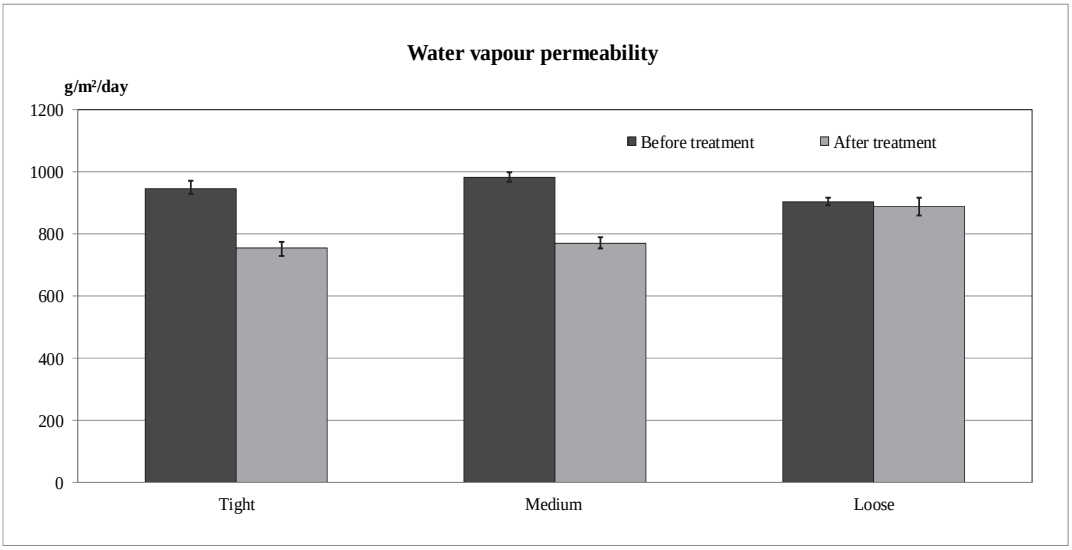

Figure 6. Water vapour permeability of samples

Table 6. Two way ANOVA for water vapour permeability

Source		Sum of squares	Degree of freedom	Mean square	F	Significance
Intercept	Hypothesis	13725778.207	1	13725778.207	4366.880	0.000
	Error	6286.309	2	3143.155		
treatment	Hypothesis	86036.574	1	86036.574	4.881	0.158
	Error	35253.119	2	17626.560		
Fabric density	Hypothesis	6286.309	2	3143.155	0.178	0.849
	Error	35253.119	2	17626.560		
treatment * fabric density	Hypothesis	35253.119	2	17626.560	40.825	0.000
	Error	5181.064	12	431.755		

According to ANOVA results, filament type (splitting treatment) and fabric density have statistically insignificant effects on water vapour permeability with significance values of $p=0.158>0.05$ and $p=0.849>0.05$ (in 95% confidence interval), respectively.

4. CONCLUSION

As a result of this study, the following conclusions can be drawn;

The air permeability of conventional filament and microfilament fabrics are quite different. Extremely lower air permeability values are obtained with microfilament fabrics. But in the literature, the studies are generally based on the comparison of the samples in the scope of the each study and there is no exact value of air permeability for knitted fabrics for a good thermal comfort. On the other hand, air permeability is a performance property which indicates the porosity of the fabric rather than being a comfort property. So, it is a deceptive conclusion to merely point out obtaining lower air permeability with microfilament fabrics and it should be more convenient to evaluate the air permeability in relation to water vapour permeability.

In respect to water vapour permeability performance, water vapour permeability of the samples shows a decrease for microfilament samples. But the loose fabric density provides a less decrease in this study. So, for a better breathability, looser structures should be selected regarding the thermal comfort. Contrary to expectations, samples do not have the same trends for water vapour permeability and air permeability. In this situation it is preferable to regard water vapour permeability than air permeability for thermal comfort evaluation.

Bursting strength results do not have a consistent trend to see the difference between conventional filament and microfilament fabrics. It is an expected result to have strength deterioration owing to alkali treatment. But, increase in loop density contributes the bursting strength of all samples after alkali treatment. This contribution compensates the strength deterioration. Thus, a significant change in bursting strength is not observed.

For further studies it should be useful to investigate the effect of knitted fabric density in a more detailed manner. Also, it should be recommended to investigate different knitted fabric performance properties.

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